They include higher pathloss, high shadowing loss (e.g., buildings, trees, or other obstacles that can block mmWave) and low diffraction, oxygen and water absorption, rain loss, and foliage loss. Therefore, when using these higher frequencies, in line-of-sight communication (LOS) is preferable. Therefore, it is important to acquire information on the suitability of LOS for connecting certain nodes.

[0018] In addition to extending cellular service into the mmWave band, dynamic spectrum access is an important technique to improve spectrum utilization. In general, dynamic spectrum access allows spectrum usage in an opportunistic manner, thus allowing service to be provided using the best available spectrum. Also, it allows for more efficient use of a scare resource as spectrum is not dedicated to only a single operator. The main functions of dynamic spectrum access come from the history of cognitive radio networks and include spectrum sensing, sharing, and management.

[0019] With novel enabling techniques and extending cellular service into the mmWave band, large spectrum band (e.g., from 1-90 GHz) will be available for dynamic access. However, different bands have different radio characteristics including propagation conditions, pathloss, diffraction, reflection, impact from terrain, foliage, LOS, and in-building penetration. In addition, different bands also have different available bandwidth and legacy usage, as well as regulatory requirements. As a result, it is not sufficient to simply select spectrum for access based on measurement reports and sensing, but to also consider other aspects as will be described below.

[0020] It may be assumed that a UE would be covered as needed with a cellular connection over traditional frequencies, like with LTE. Higher frequencies with more available spectrum would be used when additional capacity is needed, as facilitated by the embodiments discussed herein. Accordingly, certain embodiments of the present invention may be applicable to a wideband radio system (e.g., covering 1-90 GHz) where conditions can be quite different for different portions of the spectrum.

[0021] One embodiment is directed to the network creating performance maps for different portions of the spectrum. A performance metric may include, for example, Reference Signal Received Power (RSRP)/Reference Signal Received Quality (RSRQ), Signal to Interference plus Noise Ratio (SINR), spectral efficiency (SE), or throughput. Maps can include information regarding terrain, surroundings (e.g., trees, lamp posts, etc), buildings, weather, foliage, load metric, etc. These performance maps may be somewhat semi-static (i.e., slow changing for example in order of hours). The performance maps can be generated and refined using existing feedback from UEs (e.g., channel quality indicator (CQI), RSRP/RSRQ). According to this embodiment, the performance map may be specific to the radio access technology that will be used in that portion of the spectrum, such as when SE or throughput is the performance metric.

[0022] In an embodiment, the network may take semi-static performance maps and combine them with dynamic information such as available bandwidth from sensing and user specific information (e.g., location, speed, and direction). The network may then select a portion of the spectrum to use for access based on the performance maps. It should be noted that different portions of the spectrum may be selected for different users.

[0023] According to an embodiment, a central entity in the network, such as each macro base station, may select which connection in its coverage area should use higher frequencies by collecting information, for example, on: location of the UE in question, location of the access points providing connectivity that could support communication using higher frequencies, potential movement of the UE, predicted path of the UE, coverage of the small cell(s), and/or overall usage of different available bands and channels for different connectivity and their current and expected load(s).

[0024] This information may be combined with map information (outdoor and indoor) including the type of the terrain and potential blocking elements for line of sight (LOS) communication, such as trees, pillars and other supporting elements, and/or other objects with reasonable heights.

[0025] The impact of current weather and climate on coverage may also be incorporated into the map information by updating it at appropriate periods with feedback from UEs. Such weather conditions may include weather (e.g., fog, rain, snow), as well as whether foliage is present (i.e., changes with time of year, type of trees, etc.).

[0026] FIGS. **1***a* and **1***b* illustrates example semi-static performance maps for two frequency bands, according to one embodiment. In particular, FIG. **1***a* illustrates a performance map for 885 MHz and FIG. **1***b* illustrates a performance map for 2.6 GHz. In this example, downlink SINR from the best serving cell is shown and used as the performance metric. From the maps, it can be seen that performance can be quite different at different bands. The network may take these semi-static maps and add additional information such available bandwidth from sensing to come up with dynamic maps. Then, based on the maps and information such as UE location, speed, and direction, the network can select the appropriate band for access by the UE.

[0027] Therefore, certain embodiments are directed to using performance maps and related information for choosing the correct or optimum allocation of resources. This optimum allocation of resources may include the right selection of bands and channels, including for example selection of traditional lower frequencies and/or novel higher frequencies. For example, if it is known that the UE is soon going to leave the limited range small cell or is going to have difficulties in establishing linkage at high frequencies, then high frequencies and the corresponding small cell would not be used.

[0028] In some embodiments, related information to the maps may include geographical and terrain information as "visible" to usage of radio—access point location, obstacles such as trees, pillars and other objects influencing propagation and line of sight conditions etc. The related information may also include user information—user location, movement, tracks, predicted tracks of movement, etc., and weather and seasonal information as "visible" to usage of radio—foliage, rain, or snow.

[0029] In one embodiment, information on the map may be dependent on the technology to be used for wireless connectivity, if such a dependency exists for the particular information.

[0030] In view of the above, some of the main features of the invention may include the creation of the performance map with novel information elements and including spectrum sensing, the periodic update of the map based on feedback from UEs, and architecture and signalling to use the map, in combination with other system and UE metrics, for band and channel selection.